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Strength in Numbers? The Weak Effect of Manufacturing Clusters on Canadian Productivity

When measured across sectors, there is no strong link between the clustering of Canada's manufacturing industries and their economic performance in terms of either output per worker or wages. Increases in sectoral imports or exports, however, do make a difference.

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The Study In Brief

In the wake of the recent financial crisis, clusters – the spatial concentration of interrelated industries, specialized services, and customers – have again captured the attention of economists, policymakers, and consultants. Clusters are viewed by many as vital to the national economy, and a possible fix to stagnating productivity and incomes. Economic research has shown, however, that most clusters do not live up to these expectations. There is little solid evidence that clusters make regions – let alone nations – prosperous. Does this also apply to Canada?

Using detailed business location data, this *Commentary* measures the degree of clustering in Canadian manufacturing industries. It then documents changes in the spatial concentration of those industries between 2001 and 2009, and investigates whether those changes are positively associated with aggregate industry performance as measured by value added per employee or wages.

Four key results stand out.

First, Canada's manufacturing industries are less strongly clustered than those of other developed countries. High-tech sectors are not, in general, more strongly localized than other sectors.

Second, between 2001 and 2009, the spatial concentration of industries became slightly weaker, despite the stability of the overall spatial distribution of manufacturing.

Third, there is little evidence that more clustering had significant effects on average productivity or wages in manufacturing industries. The changes in clustering that would be needed to significantly boost productivity and wages nationwide are large and arguably beyond the reach of regional or even national policy.

Last, international trade has a much stronger impact on productivity than small changes in the spatial distribution of Canada's manufacturing industries. The policy message is therefore that looking at trade – and at tax policy – might provide better and cheaper solutions to improving productivity than focusing on clusters, however tempting the latter might be.

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Clusters – the spatial concentration of interrelated industries, specialized service providers, and sophisticated customers – are complex and fascinating objects (see, for example, Porter 2000, 2003). The most iconic of them – Silicon Valley, Boston's Route 128, or the North Carolina Research Triangle – have captured the attention of economists, policymakers, and consultants alike.

Around the globe, "policy makers are obsessed by Silicon Valley. The Russians claim to have built a clone of it near Moscow. Latvia aspires to create its own venture-capital industry. Universities everywhere are building high-tech 'incubators.'" Given the hype surrounding clusters – which are often viewed as providing quick fixes to complex regional or even national economic problems – some wonder even whether it can "be long before Kim Jong Un announces a North Korean venture-capital fund."[1]

Economic research has substantiated, however, that most clusters do not live up to the hype. There is indeed little solid evidence that clusters make regions generally prosperous (see, for example, Duranton et al. 2011, for a recent survey). Instead, "most incubators are a bit like roach motels: would-be entrepreneurs check in but never leave."[2] There is even less solid evidence that clusters make nations prosperous. Notwithstanding, clusters are often perceived as being "the pulse of regional local economies and, therefore, the national economy" (Katz 2010).[3]

Some organizations ascribe, for example, an important part of the widening "prosperity gap" between Canada and the United States to issues related to urbanization and the efficiency of clustered industries. According to the Institute for Competitiveness & Prosperity (2011), the Canadian-US prosperity gap – the difference in the two countries' gross domestic product (GDP) per capita – was $9,500 in 2011. Focusing on the determinants of that gap, the Institute argues that Canada is less urbanized than the United States (accounting for $2,700 of the difference) and that its clustered industries underperform their US

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1 "The View from Liverpool," *Economist* online, March 17, 2012; available online at: http://www.economist.com/node/21550239.

2 Ibid.

3 Katz, remarks at the roundtable on "Regional Innovation Clusters: Advancing the Next Economy," Metropolitan Policy Program, Brookings Institution, Washington, DC, September 23, 2010; available online at: http://www.brookings.edu/events/2010/09/23-innovation-clusters#ref-id=0923_innovation_clusters_lechleiter.

counterparts (accounting for $3,900).[4] It thus seems that the spatial and industrial structure of Canadian economic activity may have important aggregate productivity effects. Similar views are echoed by other reports on Canada's competitiveness, some going as far as to claim that "clusters allow a small geographic region to have a disproportionately large impact on the productivity of an entire nation" (Deloitte & Touche, 39). Such strong claims need to be backed by detailed analysis. I thus ask whether public policy designed to foster the clustering of economic activity – or at least not to inhibit such clustering – contributes, or could potentially contribute, to Canadian prosperity.[5]

In this *Commentary*, I investigate whether manufacturing clusters and, more generally, changes in the spatial concentration of manufacturing industries are positively and statistically significantly associated with aggregate industry performance.[6] Whereas most cluster studies have focused on the local impacts of industrial concentration by looking at specific regions, a broader national perspective is useful in at least two respects. First, when some industries cluster in a region, this might come at the expense of other regions or other industries. Given that, in the short and medium run, specialized workers and other production factors are mostly in limited supply – especially in high-tech sectors and for highly educated workers – gains from clustering in some locations might well be dampened by losses in other locations. "Microeconomic" studies of clusters at the local level thus might well overstate their "macroeconomic" effects, as some regions prosper whereas others languish, with regional decline becoming self-reinforcing for the losers.[7] Although my approach cannot rule out

4 According to the Institute for Competitiveness & Prosperity, Canada's mix of clustered industries contributes positively to reduce the gap by $1,200, whereas the effectiveness of those industries contributes negatively to increase the gap by $5,100. Underperformance is defined as follows: "in the same clustered industries, wages in Canadian firms are lower than those of their counterparts across the United States. Across all clustered industries, the average wage in Canada is 21 percent lower than the average in the United States" (Institute for Competitiveness & Prosperity 2011, 24). Observe that, quite surprisingly, the concept of clustered industries has nothing to say about how these industries are distributed across Canada – that is, it has no spatial dimension. A more detailed look at that dimension is given in what follows.

5 The obsession with clusters and their impact on national wealth is not predominantly a Canadian phenomenon. As recently stated in a report of the Brookings Institution Metropolitan Policy Program, "regional industry clusters provide a valuable mechanism for boosting national and regional competitiveness.... [M]any US industry clusters are not as competitive as they could be, to the detriment of the nation's economic strength and its capacity to generate and sustain well-paying jobs" (Mills, Reynolds, and Reamer 2008).

6 Because of data constraints, I do not look at service clusters (financial services, accounting, legal and consulting firms, resources, and resource service firms). My conclusions are not, without further research, applicable to these other sectors. Thus, one should not prematurely draw conclusions about clusters in general.

7 Focusing on cluster policies in the United Kingdom – where some eligible regions provide firms with locational incentives – Criscuolo et al. (2012, 22) find some evidence "consistent with the idea that large firms move plants from neighbouring ineligible wards into a ward that becomes eligible." They find no evidence of displacement effects or employment effects for smaller firms. However, as the authors acknowledge, their results focus on local displacement only and do not control for displacement effects that would operate at a larger regional scale. Focusing on a French neighbourhood revitalization policy, the *Zones franches urbaines* (ZFU), Mayer, Mayneris, and Py (2012, 1) find "that the policy does not create economic activity per se at the municipality level, it rather operates as a spatial shifter within municipalities, inducing existing establishments, or new establishments, to (re)locate in the ZFU part of the municipality." Briant, Lafourcade, and Schmutz (2012) reach a similar conclusion in the case of the French enterprise zone program, noting that "the program mostly worked through a displacement effect on pre-existing firms." Overall, the empirical evidence suggests that displacement effects for firms and workers due to place-based policies might be important.

the possibility that industry-wide productivity gains are driven by some specific local clusters that have a positive impact on the whole sector, the absence of such gains suggests that – on average – more clustering in manufacturing has at best local impacts only (at least over the window of 10 years considered in this paper). Second, little work has been devoted to the broader picture of how clustering and economic performance are associated at the national level (see Porter, 1990) – despite the increasing number of claims that clusters and the spatial organization of economic activity are first-order issues for the productivity and prosperity of a nation.

To help fill that gap, I take a detailed look at the spatial structure of Canadian manufacturing industries and investigate whether changes in that structure between 2001 and 2009 are associated with aggregate sectoral performance. The first step of my analysis involves measuring quite finely the spatial concentration of industries, something that has not been done for Canada until now. More precisely, I first compute state-of-the-art measures of spatial industrial concentration using micro-geographic data at the firm and plant level.[8] Exploiting the time variation in those concentration measures between 2001 and 2009, I then try to understand whether industries that experienced a tendency toward more spatial concentration performed better than other industries in terms of either manufacturing value added per worker or average production or non-production wages. I pay particular attention to "high-tech" industries – which have attracted much attention in the literature – and analyze them separately from the other manufacturing industries. I also take into account the fact that changes in the industries' competitive environment and their exposure to international competition might largely drive observed productivity changes, irrespective of any changes in the industries' spatial structure.

My key findings can be summarized as follows:

- High-tech manufacturing industries are not systematically among the most strongly clustered industries. Hence, firms in those sectors do not seem to gain more from the spatial concentration of establishments or employment than firms in other, "low-tech" sectors.
- Over the 2001–09 period, the spatial clustering of manufacturing industries generally decreased in Canada: there were fewer strongly localized industries in 2009 than in 2001. Yet, there is mild evidence that some of the most localized industries in 2001 were even more strongly clustered in 2009. This result holds true for several measures of spatial concentration and various sectoral aggregation levels. Given the general trend of less clustering, policies pushing toward the clustering of industries might be more costly and difficult to implement than previously thought.
- Larger sectoral imports, measured in total dollars, are positively associated with increases in average sectoral non-production wages (the wages paid to workers not involved in production *per se*). Larger sectoral exports, measured again in total dollars, are positively associated with changes in average sectoral manufacturing value added and average sectoral production wages (the wages paid to production workers *per se*), but export growth between 2001 and 2005 is negatively associated with changes in productivity measures between 2006 and 2009.
- Over the 2001–09 period, there was no strong link between the clustering of manufacturing industries and their economic performance in terms of either output per worker or wages. Even in the most favourable cases, the increase in the

8 My dataset contains information on both production plants and firms' headquarters. In what follows, I use, for simplicity, the term "firm" to refer to an establishment (either plant or headquarters). Most of these locations correspond to places where production occurs.

spatial clustering needed to obtain significant changes in national productivity for an industry seems beyond policy reach. In contrast, the impact of international trade on productivity is stronger and within policy reach.

- There is mild evidence that clustering is positively associated with average sectoral non-production wages in some high-tech industries. The effects of clustering were somewhat stronger at larger spatial scales, and they are roughly equal when using either firm-based measures or employment-based ones.

Measuring Manufacturing Localization in Canada Using Micro-Geographic Data

To assess the various links between clustering – which I henceforth refer to as "industrial localization" – and productivity at the macroeconomic level, I first measure the geographic concentration of manufacturing industries (see the Appendix for more information on data and industries). Doing so allows a better understanding of which industries might gain the most from clustering and an examination of broad trends in clustering over time. The question of how to measure industrial localization has long been of interest to regional economists and economic geographers. Various measures have been developed, ranging from very simple and purely descriptive ones such as location quotients, Gini coefficients, and Herfindahl indices, to sophisticated ones with precise statistical properties and theoretical foundations.[9]

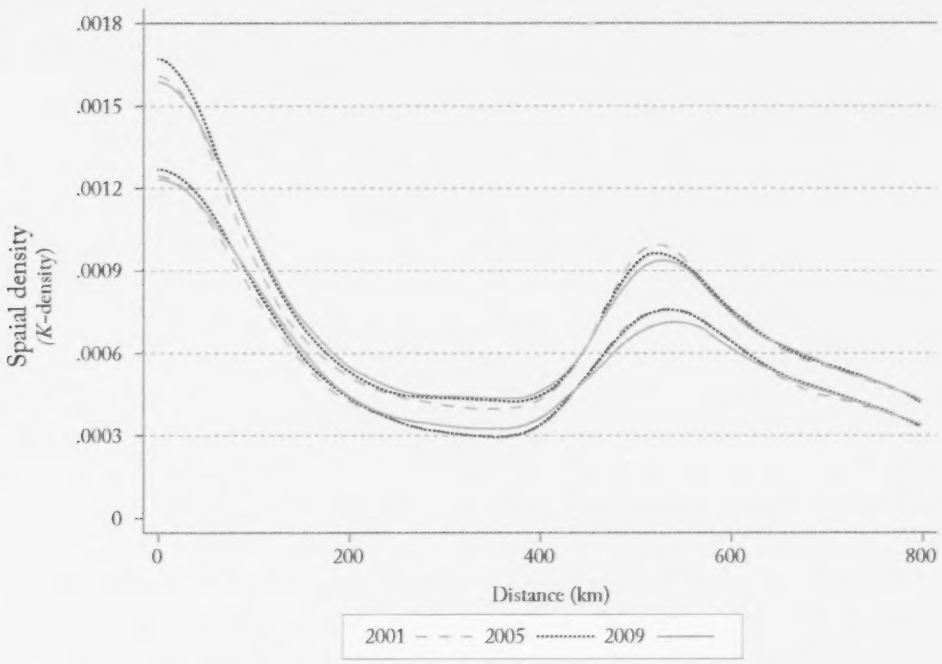
In what follows, I use a measure recently developed by Duranton and Overman (2005, 2008), which I henceforth refer to as the Duranton-Overman index. This relatively sophisticated measure looks at how close establishments are relative to each other by considering the distribution of bilateral distances among them. It provides a very detailed micro-geographic description of location patterns, and allows for statistical testing of whether or not the patterns might be due to chance.

Another advantage of this measure is that it imposes no particular form on the shape of clusters – it just provides a summary measure of how close firms are on average in an industry, irrespective of the precise spatial arrangements of those firms.[10] I construct my measures of localization – defined as the concentration in a sector in excess of the overall concentration of manufacturing in general – from large micro-geographic datasets that provide detailed information on manufacturing firms in Canada. The data are based on exhaustive information from the Canadian Business Register, are representative, and cover about the same number of firms as the Annual Survey of Manufacturers from Statistics Canada (see the Appendix for a detailed description of the datasets and the geographical scope of the analysis). My datasets provide key informations such as the firms' primary and secondary sectors of activity, their employment, and their postal code. Having access to the latter information makes those data as good as "geocoded" because firms can be located using latitude and

9 See, for example, the measure developed by Maurel and Sédillot (1999), the *D*-index of Mori, Nishikimi, and Smith (2005), generalized entropy measures (Brülhart and Traeger 2005), and various versions of the *M*-index (Marcon and Puech 2003, 2010). See Combes et al. (2008) for a comprehensive introduction, and Rosenthal and Strange (2004) for a state-of-the-art overview of the empirical literature. A new sophisticated methodology that accounts for the precise location and the shape of clusters has been recently developed by Mori and Smith (forthcoming).

10 Since I work at the national level, I do not need to worry about how to define clusters locally. This is usually a complicated problem on which theory has little to say (see, for example, Mori and Smith forthcoming). Often, clusters are based on ad hoc definitions such as metropolitan area boundaries or disk shapes; I require neither definition.

Figure 1: Distribution of Distances between Manufacturing Firms, Canada, 2001, 2005, and 2009



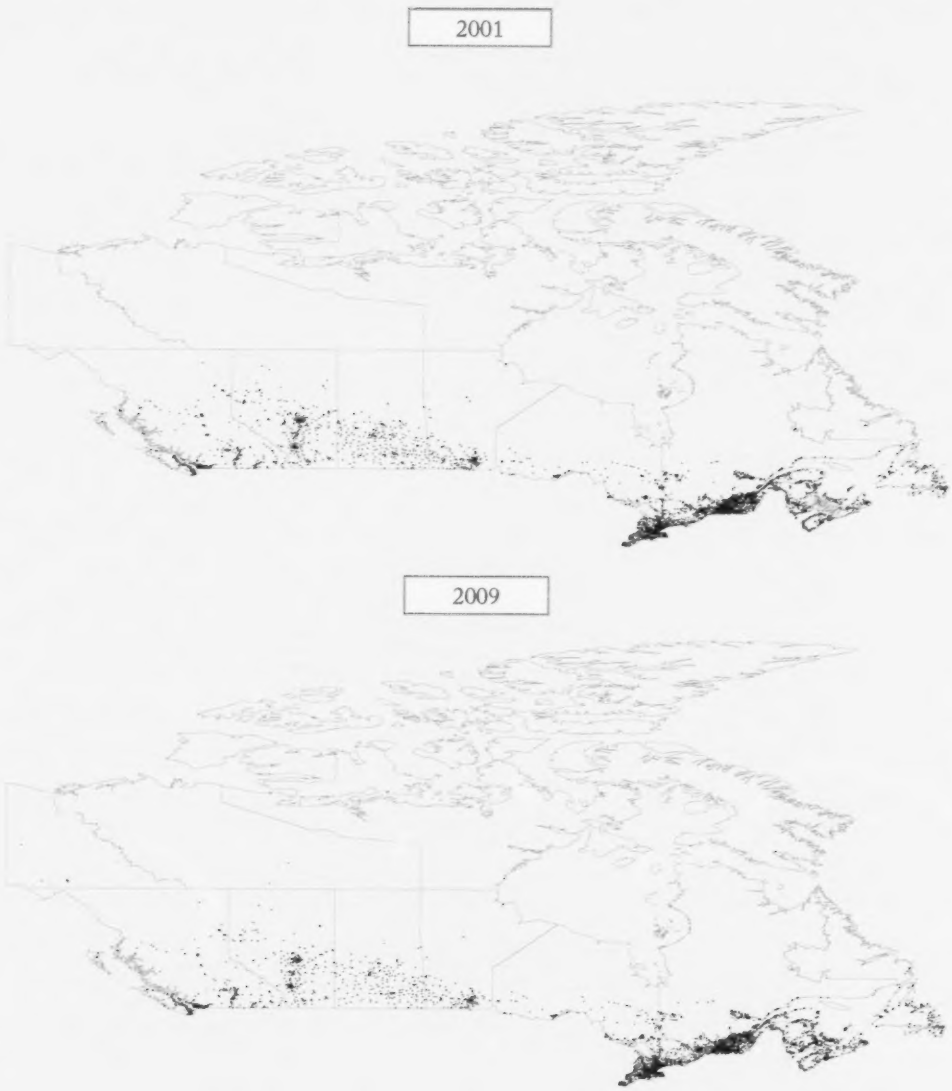
Notes: The figure depicts the 95 percent confidence bands for the Duranton-Overman measures of localization applied to a 5 percent random sample of all manufacturing firms. The confidence bands in the three years overlap substantially – that is, the observed distributions are not statistically significantly different from one another.
Sources: See the Appendix.

longitude geographical coordinates of postal code centroids.

The Lack of Strong Trends in Manufacturing Clustering

As Figure 1 shows, the overall distribution of distances between manufacturing firms did not change substantially between 2001 and 2009, despite the general decrease in the number of firms. The decline in firms might have been driven partly by the rising value of the Canadian dollar over the period, which could also explain the slight trend to more dispersion in general. Since firms increasingly rely on imported, low-priced manufacturing components and global value chains, the importance of domestic input-output linkages – and thus the benefits from clustering – are reduced. The relative stability of the overall distribution is important since it vindicates my subsequent intertemporal comparisons of the yearly measures. As stated before, my measure of localization is one of "relative concentration": how much more or less an industry is clustered compared with manufacturing in general. Hence, when comparing that measure over time and then interpreting it, I need to be sure that changes in the index have not been driven simply by changes in the overall structure of manufacturing. Changes due to, say, urbanization or the tendency of mature manufacturing industries to locate away from major urban centres in order to benefit from lower wages and land rents would not tell us much about changes in sector-specific location patterns that are important for clustering. Should the overall

Figure 2: Overall Distribution of Manufacturing Firms, Canada, 2001 and 2009



Sources: See the Appendix.

Table 1: Shares of Manufacturing Firm Pairs below Selected Threshold Distances, Canada, 2001, 2005, and 2009

Distance	Share of Distances between Firms		
	2001	2005	2009
	(percent)		
10 km	1.4–1.8	1.4–1.8	1.4–1.7
25 km	3.2–4.1	3.3–4.3	3.2–4.1
50 km	6.1–7.8	6.2–8.1	6.1–7.7
100 km	10.9–13.5	11.2–14.1	11.0–13.8
250 km	18.7–22.7	19.2–23.8	19.3–23.7
500 km	28.6–35.5	29.2–36.9	29.5–36.9

Note: The values reported are the cumulative distributions of the 95 percent global confidence bands from the Duranton-Overman *K*-densities computed for a 5 percent firm sample.

Sources: See the Appendix.

concentration of manufacturing change – without any changes in the patterns of specific industries – a comparison of my measure over a period of years might pick up this general trend. Figure 2 shows that manufacturing is strongly concentrated in Ontario and Quebec and, more generally, along the Canadian-US border. The overall degree of concentration did not change much between 2001 and 2009.

Table 1 gives a more precise idea of the general degree of manufacturing localization in Canada. To understand the table, consider the following thought exercise. If one were to pick at random 100 pairs of manufacturing firms in 2001, between 28.6 and 35.5 percent of them would have been located less than 500 km apart; in 2009, between 29.5 and 36.9 percent would be that distance apart. At a distance of 100 km, the corresponding numbers are 11.0–13.5 percent and 11.0–13.8 percent, respectively. Observe that there is a slight increase in the geographical concentration of manufacturing at a large spatial scale (more than 100 km), with no discernible effect at medium and small spatial scales (less than 100 km). As Table 1 also shows, there was slightly more concentration overall at short distances between 2001 and 2005, with a slight reversal from 2005 to 2009. The overall distribution, however, remained fairly stable: despite the steady decline in the number of firms, there were no strong changes in the overall spatial structure of Canadian manufacturing industry. My subsequent measures of localization are thus fairly comparable across years and will not simply pick up changes in the overall degree of concentration of all manufacturing firms.

To summarize, the overall spatial distribution of manufacturing in Canada remained fairly stable between 2001 and 2009. There was no clear trend toward increasing concentration or dispersion of manufacturing in general, despite a substantial decrease in the number of manufacturing firms over the period.

Industrial Clustering in Canada: An Overview

I next assess whether or not North American Industry Classification System (NAICS) 4-digit

manufacturing industries are spatially concentrated compared with the benchmark provided by the overall distribution of manufacturing.[11] The 4-digit level of analysis seems preferable to the narrower 6-digit level since it captures – at least partly – the notion of "interconnected industries." Delgado, Porter, and Stern (2010) find that, whether they use sophisticated definitions of clustered industries from the Cluster Mapping Project – which groups different industries into clusters based on co- location patterns – or simpler groupings by industry Standard Industrial Classification (SIC) 2-digit codes, both approaches yield qualitatively and quantitatively similar results. This suggests that my 4-digit definition should capture many relevant interactions.[12]

Tables 2 and 3 report my results.[13] To understand how to read these tables, take "Cut and Sew Clothing Manufacturing" (NAICS 3152) as an example. The results in Table 2 show that, in 2001, 18.11 percent of the distances between firms in that industry were less than 50 km. In other words, if one picked two firms in that industry at random, there is a probability of 18.11 percent that the two firms are less than 50 km apart. Among all manufacturing firms, however, the probability that two random picks are less than 50 km apart falls to between 6.09 and 7.77 percent (see Table 1), a statistically significant difference: firms in the "Cut and Sew Clothing Manufacturing" industry are closer than they "should be" compared with the distribution of overall manufacturing.

Tables 2 and 3 also reveal that textile-related industries, various machinery industries, and many other seemingly non-high-tech industries are among the most strongly localized, even though none ranks particularly high on the priority list of local developers and policymakers, who traditionally tend to focus more on high-tech industries.[14] Table 4 shows that high-tech industries usually do not rank among the most highly localized of sectors: only three or four rank among the 10 most localized

11 Under the North American Industry Classification System (NAICS), businesses are classified by up to six digits, with the first four indicating business sector, subsector and industry group.

12 See Duranton (2011) for a comprehensive review of why using industrial classifications makes sense for cluster-productivity analysis. One should, of course, keep in mind that my manufacturing-based definition of clusters is somewhat silent on issues of collaboration, training, and human capital, and partly on research and development (R&D). There is a vast literature suggesting that knowledge creation is highly localized at the technology level – including across industries – and enhanced by clustering (Jaffé, Trajtenberg, and Henderson 1993; Thompson and Fox-Kean 2004; Murata et al. 2011). Collaboration within clusters is an essential element of product development in some industries, such as aerospace, as is the development and maintenance of a critical mass of talented human capital, aspects that probably are not well captured by NAICS 4-digit industries. One should also note, however, that recent research shows that production activity per se has an impact on patenting at the metropolitan area level, at least for large manufacturing firms in the United States (Tecu 2011). Hence, the clustering of manufacturing industries at least partly captures R&D spillovers.

13 Tables 2 and 3 report results using the cumulative distribution of the Duranton-Overman index, which is easier to interpret. Results in terms of *K*-density are available from the author upon request.

14 Localization is very strong in the textile industries, especially at the 6-digit industrial classification level. Indeed, textile and textile-related industries are strongly concentrated in a few places around the Greater Montreal Metro Area and the Greater Toronto Metro Area. In 2001, for example, two firms in "Women's and Girls' Cut and Sew Lingerie, Loungewear and Nightwear Manufacturing" (NAICS 315231) had a probability of 47.08 percent that they would be less than 50 km apart. At the geographical scale of Canada, this implies that this sector is very strongly localized. It is worth noting that the textile sector has changed a lot in Canada over the past decade, and especially since the end of the Multi-Fibre Arrangement; see Behrens (2012) for an analysis of spatial changes in the textile industry. In particular, the textile sector has become much more high-tech than before, thus casting doubt on the usefulness of the high-tech concept.

Table 2: Ten Most Localized Manufacturing Industries by Firm Location, Canada, 2001, 2005, and 2009

NAICS	Industry	Percent of Firm Pairs < 15 km Apart	Percent of Firm Pairs < 50 km Apart
		(percent)	
	2001		
3152	Cut and Sew Clothing Manufacturing	6.65	18.11
3335	Metalworking Machinery Manufacturing	6.27	18.71
3372	Office Furniture (including Fixtures) Manufacturing	4.16	12.54
3321	Forging and Stamping	4.07	12.68
3361	Motor Vehicle Manufacturing	3.87	12.05
3151	Clothing Knitting Mills	3.80	11.78
3344	Semiconductor and Other Electronic Component Manufacturing	3.71	11.37
3131	Fibre, Yarn and Thread Mills	3.60	11.69
3132	Fabric Mills	3.66	11.40
3222	Converted Paper Product Manufacturing	3.55	10.85
	2005		
3152	Cut and Sew Clothing Manufacturing	6.05	16.77
3335	Metalworking Machinery Manufacturing	5.71	17.13
3321	Forging and Stamping	5.70	17.61
3361	Motor Vehicle Manufacturing	4.70	14.59
3372	Office Furniture (including Fixtures) Manufacturing	4.29	12.96
3344	Semiconductor and Other Electronic Component Manufacturing	3.73	11.43
3222	Converted Paper Product Manufacturing	3.50	10.70
3151	Clothing Knitting Mills	3.49	10.88
3328	Coating, Engraving, Heat Treating and Allied Activities	3.47	10.66
3261	Plastic Product Manufacturing	3.38	10.16
	2009		
3335	Metalworking Machinery Manufacturing	5.37	16.45
3152	Cut and Sew Clothing Manufacturing	5.13	14.67
3321	Forging and Stamping	4.72	14.69
3361	Motor Vehicle Manufacturing	4.52	14.03
3372	Office Furniture (including Fixtures) Manufacturing	4.07	12.38
3222	Converted Paper Product Manufacturing	3.41	10.48
3328	Coating, Engraving, Heat Treating and Allied Activities	3.33	10.26
3359	Other Electrical Equipment and Component Manufacturing	3.32	10.31
3261	Plastic Product Manufacturing	3.23	9.75
3344	Semiconductor and Other Electronic Component Manufacturing	3.21	9.88

Note: The cumulative Duranton-Overman distribution function at distance d is the sum of the K-densities up to distance d. Its value can be interpreted as the share of firm pairs in that industry that is located at a distance of less than d km from one another. Results in this table are reported for distances of $d = 15$ and $d = 50$ km.

Sources: See the Appendix.

Table 3: Ten Most Localized Manufacturing Industries by Employment Location, Canada, 2001, 2005, and 2009

NAICS	Industry	Percent of Worker Pairs < 15 km Apart	Percent of Worker Pairs < 50 km Apart
		(percent)	
	2001		
3335	Metalworking Machinery Manufacturing	6.22	18.41
3152	Cut and Sew Clothing Manufacturing	6.21	16.98
3361	Motor Vehicle Manufacturing	5.19	16.53
3372	Office Furniture (including Fixtures) Manufacturing	4.87	14.54
3151	Clothing Knitting Mills	4.70	14.56
3321	Forging and Stamping	4.65	14.41
3328	Coating, Engraving, Heat Treating and Allied Activities	4.28	13.09
3344	Semiconductor and Other Electronic Component Manufacturing	4.04	12.35
3132	Fabric Mills	4.03	12.58
3256	Soap, Cleaning Compound and Toilet Preparation Manufacturing	4.03	12.26
	2005		
3152	Cut and Sew Clothing Manufacturing	6.09	16.85
3335	Metalworking Machinery Manufacturing	5.36	15.81
3361	Motor Vehicle Manufacturing	4.78	16.60
3321	Forging and Stamping	4.72	14.68
3372	Office Furniture (including Fixtures) Manufacturing	4.47	13.45
3151	Clothing Knitting Mills	4.46	13.88
3231	Printing and Related Support Activities	4.16	11.51
3344	Semiconductor and Other Electronic Component Manufacturing	4.10	12.53
3261	Plastic Product Manufacturing	4.08	12.18
3256	Soap, Cleaning Compound and Toilet Preparation Manufacturing	4.04	12.26
	2009		
3361	Motor Vehicle Manufacturing	5.96	19.83
3152	Cut and Sew Clothing Manufacturing	5.28	15.09
3335	Metalworking Machinery Manufacturing	4.85	14.75
3255	Paint, Coating and Adhesive Manufacturing	4.36	13.41
3321	Forging and Stamping	4.09	12.81
3231	Printing and Related Support Activities	3.94	11.00
3328	Coating, Engraving, Heat Treating and Allied Activities	3.86	11.83
3256	Soap, Cleaning Compound and Toilet Preparation Manufacturing	3.74	11.48
3372	Office Furniture (including Fixtures) Manufacturing	3.73	11.38
3341	Computer and Peripheral Equipment Manufacturing	3.63	11.27

Note: The cumulative Duranton-Overman distribution function at distance d is the sum of the employment-weighted K-densities up to distance d. Its value can be interpreted as the share of firm pairs in that industry that is located at a distance of less than d km from one another. Results are reported for distances of d = 15 km and d = 50 km.

Sources: See the Appendix.

Table 4: Manufacturing Industries by High-Tech Level and Localization Rank, Canada, 2001, 2005, and 2009

		Rank, Out of 86		
NAICS	Industry	2001	2005	2009
Level 1: most high-tech				
3341	Computer and Peripheral Equipment Manufacturing	23	19	12
3254	Pharmaceutical and Medicine Manufacturing	46	47	43
3345	Navigational, Measuring, Medical and Control Instruments Manufacturing	27	24	27
3364	Aerospace Product and Parts Manufacturing	41	57	45
3344	Semiconductor and Other Electronic Component Manufacturing	7	6	10
3342	Communications Equipment Manufacturing	24	23	19
Level 2				
3333	Commercial and Service Industry Machinery Manufacturing	22	29	28
3343	Audio and Video Equipment Manufacturing	25	25	36
3332	Industrial Machinery Manufacturing	16	17	18
3346	Manufacturing and Reproducing Magnetic and Optical Media	36	50	55
3251	Basic Chemical Manufacturing	55	59	64
3252	Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing	48	45	41
Level 3				
3339	Other General-Purpose Machinery Manufacturing	15	13	13
3241	Petroleum and Coal Products Manufacturing	74	73	75
3255	Paint, Coating and Adhesive Manufacturing	29	14	14
3353	Electrical Equipment Manufacturing	35	38	42
3369	Other Transportation Equipment Manufacturing	79	72	52
3336	Engine, Turbine and Power Transmission Equipment Manufacturing	72	75	72
3259	Other Chemical Product Manufacturing	30	31	31
3253	Pesticide, Fertilizer and Other Agricultural Chemical Manufacturing	59	63	67
Level 4: least high-tech				
3324	Boiler, Tank and Shipping Container Manufacturing	65	61	73
3329	Other Fabricated Metal Product Manufacturing	28	28	32
3359	Other Electrical Equipment and Component Manufacturing	20	16	8
3335	Metalworking Machinery Manufacturing	2	2	1
3361	Motor Vehicle Manufacturing	5	4	4
3363	Motor Vehicle Parts Manufacturing	45	36	35
3362	Motor Vehicle Body and Trailer Manufacturing	81	76	78

Note: High-tech definitions are based on the US Bureau of Labor Statistics classification by Hecker (2005). His definition of high-tech industries is "input based": an industry is "high-tech" if it employs a high proportion of scientists, engineers, or technicians; level 1 industries are those whose share of such employment exceeds five times the average; level 2 industries exceed the average by between 3.0 and 4.9 times; level 3 industries exceed the average by 2.0 to 2.9 times. As Hecker shows, these industries are also usually associated with a high R&D-to-sales ratio, and they also largely – but do not always – produce goods that are classified as "high-tech" by the US Bureau of Economic Analysis. Level 4 industries satisfy partially one of these criteria for a high-tech sector. The localization rank is based on the cumulative distribution of the Duranton-Overman K-density for the samples based on firm location alone at a distance of 15 km.

Sources: See the Appendix.

4-digit NAICS sectors each year (out of a total of 86 sectors). This suggests that, if the observed location patterns convey at least some information on how much industries benefit from clustering, productivity gains due to clustering might not be the highest in those industries.[15] As Martin, Mayer, and Mayneris (2011, 192) find in a French study, "single-plant firms do internalize to a large extent the short-run productivity gains of clustering when making location choices." In a nutshell, making policy recommendations based on current clustering or on the distinction between "high-tech" and "low-tech" seems artificial.

The results in Table 3 can be interpreted in a similar way to those in Table 2. Since they are based on the employment-weighted version of the Duranton-Overman index, the unit of analysis is now the employee and not the firm. Again take "Cut and Sew Clothing Manufacturing" (NAICS 3152) as an example. In 2001, about 16.98 percent of the distances between any two employees drawn at random from two different firms in that sector were below 50 km. In other words, if we pick two employees in distinct fims in that industry at random, the probability that they work less than 50 km apart is about 17 percent. Clearly, this again testifies to the strength of localization. By comparing the weighted and unweighted results in Tables 2 and 3, we see that, for "Cut and Sew Clothing Manufacturing," firms are more clustered than employees, which suggests that – in this sector at least – small firms are more clustered than large firms. On average across all manufacturing sectors, I find that employment is slightly more clustered than firms, in line with the findings of Duranton and Overman (2005) for the United Kingdom. Hence, in Canada, clustering may generally be more about "big" firms than "small" firms. Yet, as I show below, the productivity effects of clustering are about the same for "small" and for "big" firms.

Appendix Table A-2 provides a detailed picture of the distribution of Canadian manufacturing industries over time. About 70 percent display location patterns that are unlikely to be due to chance alone. One sector in two seems to be statistically significantly more concentrated than manufacturing in general. There are also strong patterns of localization across broader sectoral groups – namely, when either 4-digit or 6-digit industries are aggregated up to higher levels. In particular, sub-industries under "Textile Mills" (NAICS 313), "Clothing Manufacturing" (NAICS 315), "Printing and Related Support Activities" (NAICS 323), "Machinery Manufacturing" (NAICS 333), and "Computer and Electronic Product Manufacturing" (NAICS 334) show strong patterns of industrial localization at more disaggregated levels.

To summarize, about 50 percent of Canada's 4-digit NAICS manufacturing sectors are statistically significantly localized, 30 percent do not display any clear pattern, and about 20 percent are statistically significantly dispersed. Localization is slightly stronger in terms of employment than of

15 The debates surrounding high-tech clusters are quite reminiscent of the "manufacturing fetish" debate in international trade. The basic line of argument is that countries (or regions) should specialize in what they are good at, not in what they would like to be good at. Hence, there is no desperate need to produce semiconductor chips if your comparative advantage lies with potato chips. As Jagdish Bhagwati (2010) has put it very neatly, "I have argued, on the other hand, that you could produce semiconductor chips, trade them for potato chips, and then munch them while watching TV and becoming a moron. On the other hand, you could produce potato chips, trade them for semiconductor chips that you put into your PC, and become a computer wizard! In short, it is what you 'consume', not what you produce, that influences what sort of person you will be and how that affects your economy and your society."

firms, and high-tech sectors do not systematically rank among the most localized, which are mainly textile and machinery related. At a finer industrial disaggregation (the 6-digit level), there are a few very strongly localized sectors.[16]

Clustering Changes over Time and International Comparisons

In analyzing changes in the localization of manufacturing industries over time, I find a clear trend toward more dispersion. This can be seen in Tables 2 and 3, where the shares of both firms and employees located either less than 15 km or less than 50 km apart tend to decrease over time (see Appendix Table A-2 for more detailed results). Generally, the share of non-localized industries gradually increased over time, while the share of clustered industries gradually decreased.[17] Globally, both the number of localized industries and the strength of localization tended to decrease. Using samples based on firm location alone, the share of localized manufacturing industries decreased from 54.7 percent in 2001 to 48.8 percent in 2009, meaning that about 6 percent of the industries that were statistically significantly more clustered than manufacturing in general in 2001 were no longer so in 2009. In 2009, about half of the manufacturing industries were statistically significantly localized, whereas about 30 percent displayed a location pattern not different from that of manufacturing in general, and the remaining 20 percent were statistically significantly more dispersed than manufacturing in general.

At the 4-digit NAICS level, clustering in Canada is slightly weaker than in the United Kingdom. Using 1996 SIC data, Duranton and Overman (2005) find that 58 percent of the 103 UK 3-digit SIC industries were statistically significantly localized and 29 percent were dispersed. At the 4-digit SIC level (239 industries), the corresponding figures are 52 percent and 24 percent, respectively. This is larger than for Canada, where clustering at the comparable 6-digit NAICS level seems weaker (only 30 percent to 40 percent of the 6-digit sectors were statistically significantly localized).[18]

In a nutshell, although localization affects an important number of Canadian industries, its impact still seems far from ubiquitous, and it appears to be slightly stronger in terms of employment than in terms of firm counts. The number of industries that do not depart statistically significantly from randomness is larger in my survey than in related studies of the United Kingdom or the United States, especially at a fine sectoral level. Furthermore, the number of localized manufacturing sectors in Canada decreased between 2001 and 2009, although the overall distribution of manufacturing remained fairly stable. My analysis cannot tell why manufacturing is less clustered in Canada than in other developed countries, but is it

16 These results are all consistent with previous findings in the literature. See, for example, Ellison and Glaeser (1997); Duranton and Overman (2005, 2008); and Barlet, Briant, and Crusson (2009).

17 The finding holds true for various sample definitions and different weighting schemes.

18 Over the 2001–09 period, however, localization increased even more for some of Canada's most localized industries. To compare the extent of clustering in Canada with that observed in the United States, I also computed Ellison-Glaser indices at different spatial scales, which revealed that fewer industries were strongly localized in Canada than in the United States, especially at the 6-digit NAICS level.

possible that various federal and provincial policies prevent "natural" clustering from happening?[19]

"Paths to Prosperity" or "Roach Motels"? The Tenuous Link between Aggregate Clustering and Productivity

Canadian manufacturing industries, on average, are less clustered than either their US or their UK counterparts. This difference could explain at least partly the widening "prosperity gap" between Canada and the United States that the Institute for Competitiveness & Prosperity has highlighted. Should, therefore, significant productivity gains be expected from stronger clustering of specific manufacturing industries?

To answer this question, I focus on the overall spatial distribution of these industries, not on specific clusters. The reason is that we know fairly well that clustering has a small positive causal effect on productivity and wages in the areas where firms cluster (see, for example, Duranton 2011; Duranton et al. 2011).[20] A study by Spencer et al. for Canada finds, for example, that "the overall prevalence of clustering within a city-region is positively associated with income levels and employment growth" (2009, 1). Unfortunately, it is not clear whether this finding is just picking up urban scale effects ("agglomeration economies") since the benchmark for the analysis is the overall spatial distribution of economic activity, not the distribution of individual sectors relative to that distribution, as is the case in my study. Note also that we know much less about the links between clustering and productivity at the aggregate macroeconomic level. The reason is that studies that focus on the regions where firms and employment cluster disregard the fact that these firms and workers must be drawn at least partly from somewhere else – either other regions or other industries.[21]

Assume, for example, that a cluster policy provides subsidies to attract biotech firms to a specific region or to create new ones there. In the short run, biotech firms are in limited supply, so that even if more clustering in one location raises productivity there, by symmetry less clustering in another location could partly offset these gains. The net effect is unclear and depends on the elasticity of supply of both new biotech firms and existing firms coming from somewhere else. Unfortunately, little is known about the supply elasticity of new firms and the locational responses of existing firms to cluster policies. Rosenthal and Strange estimate

19 As an example, Bombardier was permitted to acquire de Havilland in 1992 and obtain contracts from the Ontario government on condition that the manufacturing activities involved were kept in that province. It is conceivable – yet far from sure – that, if such policies were removed, stronger clusters would form. Observe also that some regional development policies actively push for the de-concentration of industries. One example mentioned by reviewers is the Alberta oil sands buyer-seller strategy, which aimed to deconcentrate the production of scarce assembly components for the supply chains of oil sands megaprojects from Leduc-Nisku.

20 As Duranton (2011, 33) points out, "doubling the specialization in a typical activity and area is associated with an increase in productivity of around 4 percent. This number is lower in some industries and higher in others (although it seldom goes above 10 percent). Even for industries with strong clustering effects, say, an elasticity of 8 percent, it takes more than a trebling of the specialisation of the cluster to see labour productivity increase by 10 percent. In conclusion, there are positive effects of clustering but the literature is also strongly suggestive that it takes extremely large increases in specialisation to get more than marginal effects on local productivity and wages."

21 When focusing on subsidies to underperforming regions, positive effects might also come from reduced unemployment via the creation of new firms and the expansion of existing ones; see Criscuolo et al. (2012).

for the case of the US software industry that "adding one hundred software workers to [a] one mile ring would generate 0.04 births [of firms] and 1.117 additional employees at new establishments" (2003, 385). Put differently, there are slightly more firm births in bigger clusters and the employment size of new firms is larger there, but the effects are quantitatively small. Focusing on regional grants to attract foreign greenfield investments in the United Kingdom, Devereux et al. find "some evidence that grant offers influence where existing firms choose to locate new plants. The marginal effect is very low at 0.0001, implying that an increase in the expected grant of £100,000 [$160,526] is associated with a 1 percent increase in the probability of location, i.e. from 1% to 1.01%" (2007, 431). Interacting the grant with a measure of industrial clustering in a location, they find an effect that is three times larger, but that still remains arguably small. Criscuolo et al. (2012) find that a 10 percent investment subsidy in the United Kingdom's Regional Selective Assistance grants program – designed to help the manufacturing sector in underperforming regions – has a 3.5 percent employment impact on the assisted regions via the net creation of new firms. The key message in all cases is that the effects are economically rather small, irrespective of their statistical significance.

The Effects of Clustering on Productivity

I use the measures of localization I compute above to investigate whether increases in the spatial concentration of industries are linked to productivity gains. I measure productivity at the industry level in three different ways: by two types of wages and by value added. To isolate the effect of clustering on these productivity measures, I control for a number of other changes – especially in international exposure and in sectoral structure – that might be associated with sectoral productivity gains. In particular, I control for the intensity with which the sectors import and export goods internationally, and I also control for overall changes in both the size of each industry (as measured by total sectoral employment) and intra-industry concentration (as measured by the number of firms and the distribution of employment across firms). More details on the empirical model can be found in Box 1; detailed estimation results are relegated to the Appendix.

Table 5 summarizes my key findings. As the table shows, there are two key messages. First, changes in the degree of clustering do not affect wages strongly in the aggregate. Changes in manufacturing wages across all industries are essentially centered on zero.[22] Thus, on average, clustering is unlikely to yield broad manufacturing wage gains across all industries. Second, when considering all industries jointly (the top panel of the table), on average neither production nor non-production wages are positively associated with increases in the degree of clustering. To obtain a finer picture, I look separately at the effects on high-tech industries (the bottom half of the table). By comparing the bottom and the top panels, it is evident that the effect of clustering on wages is stronger in the high-tech industries than across all industries, especially with respect to production wages. Clustering thus seems to have a stronger effect on wages in the high-tech industries, although the magnitude of the overall effect might still be close to zero.

22 My estimates do not have very tight bounds, partly because I have data only for three years (2001, 2005, and 2009) and because the analysis identifies changes in wages that are driven by changes in the degree of clustering. If the degree of clustering does not change much over time, the estimates have necessarily large bounds. See Appendix Table A-3 for more information on the point estimates and the estimation bounds.

Box 1: Empirical Specifications

I run two different sets of regressions to assess the links between clustering and productivity. First, I look at simultaneous changes in clustering and my productivity measures. To isolate the impact of clustering on those measures, I control for a number of other changes that might be associated with sectoral productivity gains. In particular, I control for the intensity with which the sectors import and export goods internationally, and I also control for overall changes in both the size of each industry (as measured by total sectoral employment) and intra-industry concentration (as measured by the number of firms and the distribution of employment across firms). I also control for time trends that are common to all industries, and include a set of "industry dummies" that control for unobserved industry-specific time-invariant characteristics.

I estimate two sets of coefficients. First, I look at the average impact of clustering on productivity across all 86 manufacturing industries. Second, I look at whether "high-tech" industries display a different behaviour than "low-tech" industries. Indeed, "high-tech" industries might stand to gain more from clustering than do other industries – although, as I show in the text, high-tech industries are not more clustered in general.

My first specification is a standard panel of the following form (all continuous variables are taken in logs):

$$prod_{it} = \alpha_0 + \alpha_1 CDF_{it}(d) + X'_{it}\beta + \varepsilon_{it} \qquad (1)$$

where *prod* is a measure of productivity in sector *i* and year *t* (manufacturing value added; average production wages; or average non-production wages); *CDF(d)* is the cumulative *K*-density of the Duranton-Overman measure at distance *d* for year *t* and sector *i*; and *X* is a vector of controls (import and export values; industry structure; industrial concentration across firms).

Second, to alleviate somewhat problems of simultaneity when regressing measures of productivity on measures of spatial concentration, I use a lagged differenced specification as follows (all continuous variables are taken in logs, and changes are expressed as differences in logs):

$$\Delta prod_{i,09\text{-}06} = \alpha_0 + \alpha_1 \Delta CDF_{i,05\text{-}01}(d) + \Delta X'_{i,05\text{-}01}\beta + \varepsilon_i \qquad (2)$$

where I regress changes in productivity between 2006 and 2009 (or 2005 and 2007 to get around the recent financial crisis) on previous changes in clustering and other control variables between 2001 and 2005. Although I cannot lag my variables deeply and thus am prone to the critique of serially correlated unobservables, this specification still alleviates the most obvious "contemporaneous" simultaneity problems.

In both cases, I estimate a baseline specification where I impose the same coefficient on the *CDF* for all industries. I also then estimate a separate coefficient for high-tech industries.

Table 5: Links between Industrial Clustering and Average Wages, Manufacturing Industries

	Average Change in Wages *(percent)*	
	10% Increase in Clustering	**100% Increase in Clustering**
	All Manufacturing Industries	
Sectoral change in wages of production workers	–1.58 to 1.70	–10.35 to 12.47
Sectoral change in wages of non-production workers	–2.46 to 0.31	–15.69 to 2.16
	High-tech Manufacturing Industries	
Sectoral change in wages of production workers	–0.81 to 4.48	–5.46 to 36.38
Sectoral change in wages of non-production workers	–1.97 to 3.00	–12.75 to 23.09

Notes: All results are reported for the cumulative measure of Duranton-Overman at a distance of 15 km. The 95 percent confidence bands are reported using heteroskedasticity robust standard errors. See Appendix Table A-3 for further details.

Sources: See the Appendix.

Consider the bottom half of Table 5, and take the midpoint of each "confidence interval." The "average effect" of a doubling in clustering would then be to increase average production wages by 15.46 percent and average non-production wages by 5.17 percent. What would it take to double the clustering? Consider "Industrial Machinery Manufacturing" as an example. Assume, for simplicity, that we could create a single new cluster by relocating only "isolated firms" – that is, firms that are more than 15 km away from the closest firm in their industry. How many firms would need to relocate to double the localization measure? A simple calculation shows that 97 firms or, equivalently, 18 percent of the firms in that sector would need to do so. Stated differently, such a policy would require about one-fifth of the firms in the "Industrial Machinery Industry" to move and cluster into a disk with radius of 7.5 km to get an increase of about 15 percent in production wages and 5 percent in non-production wages.[23] The results are similar for other industries in the high-tech category. Doubling the localization measure of the "Pharmaceutical and Medicine Manufacturing" industry, for example, would require a new cluster involving 32 firms (close to 14 percent of all firms in the industry); the "Electrical Equipment Manufacturing" industry would need

23 The figure of 18 percent is obtained as follows: 3.15 percent of the distances between firms are below 15 km; with 546 firms in that sector, there are (546 × 545)/2 = 148,785 different distances between all possible pairs of firms, and of these, 148,785 × 0.0315 = 4,693 are less than 15 km apart. Consider a new cluster that is made of previously isolated firms – that is, firms that do not affect the localization measure at that distance anyway. To double the localization measure, we need the cluster to have 4,693 distances below 15 km. Solving $(x \times (x-1))/2 = 4{,}693$ for x, we find about 97 firms, or 18 percent of the industry total of 546 firms.

76 firms (about 15 percent of all firms in the industry) to relocate to a new cluster. Clearly, such large numbers are beyond the reach of regional policy.[24] Measures of localization based on employment yield similar results: large changes in employment are required to obtain sizable productivity gains. In other words, the movement of large firms would be required (see Greenstone, Hornbeck, and Moretti 2010), yet such firms are scarce and both more difficult and costly to move.

Two caveats should be kept in mind with respect to the foregoing computation. The first is that the figures I report are probably optimistic and might provide upper bounds. We need to be able to draw upon isolated firms – otherwise, relocating firms reduces the localization measures of the places firms leave while raising it for the place firms go). We also need to be sure that the gains come from clustering and are not due to some other unobserved features that are correlated with both productivity/wages and the location of the industry. For example, the industry might be located in a region or urban area where high wages are driven more by urban scale than by within-industry clustering.[25] Given the aggregate nature of my data, I cannot control for this effect. Finally, decreasing returns to clustering overtake the benefits beyond some size of the cluster. Congestion, high land prices, and competition in product and factor markets will offset productivity gains and might even significantly hurt some industries when clusters become too large.[26]

The second caveat is that, in the above examples, I assume that the supply of firms is fixed. This is, of course, too stark an assumption. Cluster policies – as well as tax policies – are designed at least partly to provide incentives to create new firms; that is, more clustering in one location might not come at the full expense of less clustering somewhere else. To see that my figures do not change by a lot when I drop the assumption that the supply of firms is fixed, consider again the "Industrial Machinery" industry but assume now that some of the firms in the cluster are new firms that do not relocate from somewhere else. Let me take the figure from the findings by Criscuolo et al. (2012) for the United Kingdom as my benchmark: a 10 percent investment subsidy increases employment via the creation of new firms by 3.5 percent in underperforming regions. Let me consider that, during the process of doubling the clustering measure, 3.5 percent of new firms in the industry are created in the cluster. In that case, instead of moving 97 out of 546 firms, we would need to move

24 Martin et al. (2011) also find in the case of France that substantial productivity gains from clustering would require that a very large amount of firms be spatially reshuffled.

25 Recent work on US counties suggests that clustering effects are rather insignificant for high-tech industries, whereas urbanization effects (metropolitan scale) matter much more. This is a recurrent finding in the empirical literature (see, for example, Belal, Partridge, and Rickman 2012, for recent evidence). The problem of urban scale's driving observed wage gains more than clustering itself also poses problems for Spencer et al. (2009).

26 Observe that it is not entirely clear where the gains from clustering go, or if clusters indeed generate wealth for a broad class of agents. As Edward Glaeser (2012) puts it neatly, taking the case of New York's financial cluster as an example, "[a]s finance's success drove up rents, many businesses in other sectors had to leave Manhattan. Between 1998 and 2008, the island lost more than 75,000 jobs in manufacturing, transportation, and warehousing, and wholesale trade. Offsetting that decline was a gain of more than 100,000 jobs in consumer industries – retail, food and accommodation, and arts and entertainment – catering to well-heeled residents and tourists. (While that's diversification of a sort, it's hard to imagine that Manhattan can sustain itself primarily as an entertainment hub.)"

only 94 firms.[27] Even if I assume an implausibly high elasticity of new firms of 30 percent, the relocation of 68 firms (12.45 percent of the industry) would still be necessary.

Clustering and Productivity: It's Mostly about (Small) Firms

Another interesting finding of my analysis is that the effects of employment-based measures of clustering on productivity are generally slightly smaller (in absolute value) than firm-based measures of clustering, save for some high-tech industries.[28] Hence, there seems to be a stronger association between the clustering of firms and productivity and wages than between the clustering of employment and productivity and wages. We observe, however, more clustering in terms of employment than of firms. This suggests that it might be easier to cluster employment than firms – because, for example, firms are large – but that productivity gains are more likely to come from having more small firms locally (see, for example, Henderson 2003). Armington and Acs (2002) and Rosenthal and Strange (2003) find that having more small firms locally also increases the birth rate of new firms in industrial agglomerations in the United States. In the former study, which focuses on US labour market areas, variables such as "industrial density" and "population growth" are key determinants. The latter study provides evidence for own-industry effects at small spatial zip-code scales. My own results, based on micro-geographic measures, suggest that own-industry effects on firm counts are slightly more important than those on employment for understanding the positive link between increased clustering and greater productivity. This holds true both at small (15 km) and larger (50 km) spatial scales.

Past Clustering and Future Productivity?

So far, I have investigated how changes in clustering affect changes in productivity measures. My estimates might be biased, however, because productivity also arguably influences clustering. For example, employees in certain sectors might be attracted to places where wages are high – that is, where firms in that industry are productive – so that the link between clustering and productivity runs from the latter to the former, not the other way round.[29] To control at least partly for this potential problem, I investigate how changes in clustering – and other variables, such as sectoral imports and exports – between 2001 and 2005 are associated with subsequent changes in productivity. More precisely, I try to see whether industries that grew more spatially concentrated between 2001 and 2005 displayed stronger subsequent changes in productivity.

The key message from this second analysis is that changes in clustering between 2001 and 2005 basically are not associated with subsequent changes in productivity measures (see Appendix Table A-4). If anything, the productivity effects are slightly negative when associated with changes using densities based on firm location alone, and not associated at all when using densities based on

27 The doubling is achieved since, if 94 firms move to the cluster and the elasticity of new firms is 3.5 percent, then 94 firms relocate and 3 firms are born, to make a cluster of 97 firms.

28 More firms in an area working on the same thing might drive innovation and productivity through spillovers, especially when incomplete contracts are hard to enforce locally across firms. An alternative explanation might lie in the different business culture of small firms (Rosenthal and Strange 2003).

29 This is what economists call a problem of "reverse causality." As Duranton et al. (2011) point out, the bias from this problem seems to be relatively small in most studies dealing with the productivity effects of clusters.

employment location – except for non-production wages, where there is some weakly positive effect. Hence, sectors that experienced stronger clustering between 2001 and 2005 seem, everything else equal, to have performed a bit worse in later years. This is reminiscent of the finding of Duranton et al., using French data, that "[s]ectors that lose jobs and are in decline are those that concentrate" (2011, 77).[30]

In short, my analysis reveals that the link between sectoral productivity and localization at the macroeconomic level in Canada between 2001 and 2009 is at best tenuous. The effects of stronger clustering on industry performance are mostly insignificant, when looking at both contemporaneous and lagged changes in clustering. The only significant effects are, in fact, negative on average across all industries, with some mild evidence that more clustering in some high-tech industries is positively associated with wages.[31] To summarize, over the 2001–09 period, there was no strong link between the overall spatial structure of manufacturing industries and their economic performance in terms of either output per capita or wages. My estimates suggest that to get positive effects requires quite substantial changes in the spatial structure of manufacturing. Those changes are likely to be beyond policy reach.

Trade and Productivity: A Stronger Link

Although the link between the degree of localization and aggregate productivity is at best tenuous, the data reveal a much stronger – and statistically more significant – link between international trade and productivity.[32] The value of imports positively influences average non-production wages in almost all my estimations, while the value of exports positively influences average production wages and value added per worker (detailed results are presented in Appendix Tables A-3 and A-4).

From Table 6, which summarizes my key findings, there are again two main messages. The first is that a doubling of international trade (either imports or exports) is likely to have a positive effect on the wages of both production and non-production workers. However, production workers seem to benefit more from export opportunities, while non-production workers seem to benefit more from import opportunities.[33]

Second, and contrary to the scenario of a doubling of industrial clustering, the doubling of international trade is a policy that might achieve success through further trade integration, new free trade agreements such as that planned with the

30 Canada's textile-related industries seem to be an exception. Preliminary analysis suggests that this sector – which has been in decline especially since the end of the Multi-Fibre Arrangement – experienced significant spatial de-concentration; see Behrens (2012).

31 I also carried out the same analysis using the NAICS 6-digit level classification. The results are basically the same. However, I do not have import and export data at that level of aggregation and thus have had to exclude them.

32 Clustering itself might affect firms' export and import performance, but relatively little is known about such an impact; see, however, Koenig, Mayneris, and Poncet (2010) for the case of French exporters. It is also worth emphasizing that cluster proponents are well aware of the importance of international trade for the economic performance of clusters and industries. Trade promotion programs and international market intelligence programs are often part of cluster strategies.

33 Looking at the effects of changes in trade on changes in wages (see Appendix Table A-4), I find that past changes in imports are positively associated with subsequent non-production manufacturing wage changes and very weakly positively associated with production manufacturing wage changes. Past export growth plays the opposite role: sectors that expanded exports between 2001 and 2005 suffered more in terms of manufacturing value-added changes in the 2006–09 period; the results for the latter period, however, are affected by the recent recession and trade crisis. Sectors that expanded strongly internationally before the crisis were hit harder than sectors that did not expand strongly.

Table 6: Links between International Trade and Average Wages, Manufacturing Industries

	Average Change in Wages *(percent)*	
	100% Increase in Imports	**100% Increase in Exports**
	All Manufacturing Industries	
Sectoral change in wages of production workers	–2.40 to 5.57	3.02 to 10.38
Sectoral change in wages of non-production workers	3.39 to 18.39	–1.68 to 6.47
	Controlling for Different Location Patterns in High-tech Industries	
Sectoral change in wages of production workers	–1.52 to 5.40	2.98 to 9.24
Sectoral change in wages of non-production workers	3.97 to 18.51	–2.30 to 6.12

Note: All results are reported using yearly sectoral imports and exports from Industry Canada. The 95 percent confidence bands are reported using heteroskedasticity robust standard errors. See Appendix Table A-3 for further details.

Sources: See the Appendix.

European Union, or the dismantling of remaining tariff and non-tariff barriers. Hence, trade policy seems both a more realistic and a more cost-efficient way of promoting productivity gains at the aggregate level. Of course, trade policy is potentially less flexible as to its targeted geographical effects than is cluster policy. In particular, greater trade integration might work strongly against some regions and in favour of others. Yet, if cluster policy is primarily concerned with efficiency issues – as seems to be the case in Canada – this does not seem to be a major downside.

A final word of caution is in order. Although trade seems to have a stronger impact than clustering on productivity and wages, one should keep in mind that cross-border trade might occur within larger North American clusters (such as the automotive cluster). In such a case, my results would be biased against clusters and in favour of trade. Yet, I believe it is fair to say that the spatial extent of cross-border clusters is such that it is hard to link them to the benefits that cluster proponents usually have in mind. Clusters are defined by frequent interactions across firms, face-to-face communication, labour market pooling, knowledge spillovers, and the sharing of specialized intermediate goods and services. All these things usually happen within fairly compact geographical units, not over hundreds of kilometres.

Conclusions and Policy Recommendations

From my analysis, there are four takeaway messages. First, Canada's manufacturing industries are less strongly localized than those in either the United Kingdom or the United States. Furthermore, high-tech sectors are not generally more strongly localized than other sectors. Second, over the 2001–09 period, industrial localization became slightly weaker, despite the relative stability of the overall distribution of manufacturing. Third, there is little evidence that stronger clustering at either 15 or 50 km distance had significant effects on average productivity or wages in the manufacturing industries. Finally, even in the most favourable

cases, the changes in aggregate spatial structure that would be needed to boost productivity and wages significantly at the national level are large and arguably beyond the reach of regional or national policy.

We should not expect cluster policies – be they local or national – to provide miraculous solutions to the productivity problem. The reasons for this are that the overall gains at the national level are unlikely to be very large, that industries are very heterogeneous in terms of their productivity responses to clustering, and that "natural" clusters already exist that allow industries to realize most of the benefits of agglomeration (see, for example, Duranton et al. 2011). My most robust finding is a much stronger statistical association at the macro level between international trade and productivity than between clustering and productivity. More exports are always strongly positively associated with both higher manufacturing value added and average wages for production workers, whereas more imports are always strongly positively associated with average wages of non-production workers. The policy message is thus that international trade has a much stronger impact on productivity than small spatial changes in the aggregate distribution of Canada's manufacturing industries. Looking at trade (and better tax policy) thus might provide better – and cheaper – partial solutions to the "productivity problem" than looking at clusters. Alternatively, another cheap solution might lie in the do-no-harm approach, by not enacting policies that prevent natural clusters from emerging. Of course, there is no silver bullet: neither clusters nor trade nor tax policy will completely eliminate the productivity gap with the United States.

At the end of the day, one must ask whether governments ought to get more actively involved in cluster strategies and whether they can do something about clusters. There is no broad consensus on these questions in the profession. Some authors are careful to assess the value that governments can provide in the formation and support of clusters.[34] Others propose that government asset allocation goes further toward achieving regional development goals when successful coordination exists with local resources such as civic and social capital and local institutions. Especially in the wake of the recent financial crisis, the question of the merits of active cluster policies has again attracted a lot of interest, in both Canada and the United States.

North of the border, some assert that "Toronto's business leaders need to take action, with support from government…to formulate a cluster strategy" (Blackwell 2012). South of the border, former secretary of commerce Gary Locke recalled that clusters are a strategy of the Obama administration to devise a "new growth model" – one that is export oriented, high-tech, innovation intensive, low carbon, and leads to sustained and shared growth for all, as "America simply cannot afford to return to the pre-crisis status quo where we relied on bubbles, debt, and financial speculation."[35] These views – that government can do something about clusters and should play an active role – are not shared by all, however, especially among academics and in the private sector. The reason being that – as

34 Katz and Muro, for example, argue that "policy makers at all levels should adhere to a set of core general principles when pursuing cluster-based development strategies….Clusters can't be created out of nothing and cluster initiatives should only be attempted where clusters already exist" (2010, 6).

35 Gary Locke: remarks at the roundtable on "Regional Innovation Clusters: Advancing the Next Economy," Metropolitan Policy Program, Brookings Institution, Washington, DC, September 23, 2010; available online at: http://www.brookings.edu/events/2010/09/23-innovation-clusters#ref-id=0923_innovation_clusters_lechleiter.

Helen Greiner, co-founder of iRobot, reminds us – clusters just "happen": "what they [governments] probably shouldn't do is try and create clusters. You know, the robotics cluster in Massachussetts existed, it was just self-awareness happening…it would be probably a less impactful way to use federal funds to try and create clusters, that would be a huge job."[36]

36 Ibid.

APPENDIX: SUPPLEMENTAL FIGURES AND TABLES

Industry Definitions

In this paper, I present results at the North American Industry Classification System (NAICS) broad 4-digit level (86 industries), although the results are similar to those using the more detailed 6-digit level (259 industries). That broader definition at the 4-digit level is also more closely related to what cluster proponents usually use in their analysis – though it is important to keep in mind that I look only at single industries. The Institute for Competitiveness & Prosperity's *Canadian Cluster Data*, for example, provides a variety of information on clustered industries that are based mainly on industrial aggregations determined by the co-location patterns of NAICS 6-digit industries and that strongly resemble NAICS 4-digit industries.[37]

Datasets and Sources

My primary data source is the proprietary Scott's *National All Business Directories Database*, which contains information on 54,379 Canadian manufacturing firms or establishments in 2001; 50,404 in 2005; and 46,391 in 2009. The sample sizes shrink over my study period due to the increasing deindustrialization that is also observed in other developed countries; see, for example, Duranton et al. (2011) for France. The Scott's database has wide coverage and a sample that is very similar to that of Statistics Canada's Annual Survey of Manufacturers (ASM) in terms of size and province-level breakdown of firms (see Appendix Table A-1). Therefore, it provides a fairly accurate picture of the overall Canadian manufacturing structure.

Most firms report the following information: location (6-character postal code); the firm's primary 6-digit NAICS code and up to four 6-digit secondary NAICS codes; the year the firm was established; its employment; and whether it is an exporter. I geolocate the firms using latitude and longitude data of postal code centroids obtained from Statistics Canada's Postal Code Conversion Files (PCCF), using the postal code data for the next year. Doing so allows me to take into account the six months' delay in the updating of postal codes in the PCCF bases. To compute the Ellison-Glaeser indices, I also associate firms with standard geographical information (provinces and territories; economic regions; census divisions and subdivisions).

My international trade data come from Industry Canada and cover the 1992–2008 period. The data report, for all 86 NAICS 4-digit sectors, Canadian imports from and exports to all other countries in the world. Trade values for both imports and exports are reported in current Canadian dollars. I keep the data for 2000, 2004, and 2008, and drop two "countries" from my sample: Canadian re-exports, and "High Seas;" both items – though reporting non-zero values for some industries in some years – contribute only very little to the overall values of imports and exports.

The productivity data are at the national level and come from Statistic Canada's ASM (CANSIM Tables 301–0003 and 301–0006). I use the variables "manufacturing value added," "manufacturing employment," "non-manufacturing employment,"

37 Examples include "Communications Equipment," "Footwear," "Medical Devices," "Publishing and Printing," "Textiles," "Communications Equipment," and "Chemical Products"; see Institute for Competitiveness & Prosperity, "Canadian Cluster Data"; available online at :http://www.competeprosper.ca/ index.php/clusters/studies/.

"manufacturing wages," and "non-manufacturing wages."

Geographical Scope

I compute the densities of bilateral distances across establishments in a sector following Duranton and Overman (2005, 2008). In my computations, I set the cutoff distance $\overline{d}$ for the K-density estimation to 800 km. The reason for that choice is that the interactions across "neighbouring cities" mostly fall into that range in Canada. In particular, a cutoff distance of 800 km includes interactions within the "western cluster" (Calgary, Edmonton, Saskatoon, Regina); the "plains cluster" (Winnipeg, Regina, Thunder Bay); the "central cluster" (Toronto, Montreal, Ottawa, Quebec City); and the "maritime cluster" (Halifax, Fredericton, Charlottetown). Setting the cutoff distance to 800 km thus allows me to account for industrial localization at both a small spatial scale and also a larger interregional scale, for which market-mediated input-output and demand linkages, as well as market size, matter more.

Table A-1: Comparison of Scott's National All Business Directories Database and Statistics Canada's Annual Survey of Manufacturers, Selected Years

	Statistics Canada, Annual Survey of Manufacturers		Scott's National All Business Directories Database		
	2003	2005	2001	2005	2009
	(number of firms)				
Alberta	4,882	7,750	3,933	3,455	3,581
British Columbia	6,933	11,942	6,219	5,371	4,991
Manitoba	1,481	2,307	1,654	1,481	1,263
New Brunswick	963	1,533	1,395	1,258	1,175
Newfoundland and Labrador	522	765	576	540	472
Nova Scotia	1,106	1,944	1,676	1,495	1,296
Ontario	21,470	34,184	21,306	20,966	19,637
Prince Edward Island	211	351	328	327	280
Quebec	15,251	23,042	15,939	14,166	12,560
Saskatchewan	1,008	1,804	1,353	1,305	1,091
All territories			0	40	45
Total	**53,827**	**85,622**	**54,379**	**50,404**	**46,391**

Note: The 2003 Annual Survey of Manufacturers reports only employer firms with sales exceeding $30,000 whereas the 2005 survey reports information for manufacturing firms (including forestry, which is absent in the 2003 survey) without a sales threshold. Industry Canada's Canadian Business Patterns 2008 reports about 56,000 employer establishments in manufacturing.

Sources: Author's calculations from province-level breakdown of manufacturing firms (NAICS 31–33) in Scott's National All Business Directories Database, 2001, 2005, and 2009; and Statistics Canada, Annual Survey of Manufacturers, 2003 (CANSIM Table 301–0003) and 2005 (CANSIM Table 301–0006).

Table A-2: Yearly Summary Statistics for the Duranton-Overman Density Estimates

	2001			
	Unweighted		Weighted	
	Number	*Percentage*	*Number*	*Percentage*
Localized	47	54.65	47	54.65
Random	26	30.23	29	33.72
Dispersed	13	15.12	10	11.63
	2005			
	Unweighted		Weighted	
	Number	*Percentage*	*Number*	*Percentage*
Localized	48	55.81	42	48.84
Random	24	27.91	33	38.37
Dispersed	14	16.28	11	12.79
	2009			
	Unweighted		Weighted	
	Number	*Percentage*	*Number*	*Percentage*
Localized	42	48.84	34	39.53
Random	29	33.72	39	45.35
Dispersed	15	17.44	13	15.12

Note: Results are reported for 86 4-digit NAICS industries.

Table A-3: Results for the Panel Regressions

	Measures Based on Firm Counts, Concentration Up to Distance of 15 km								
	1	2	3	1	2	3	1	2	3
Log of imports	0.1032 (0.0543)*	0.0215 (0.0283)	0.1458 (0.0489)***	0.1033 (0.0542)*	0.0269 (0.0245)	0.1506 (0.0472)***	0.0789 (0.0553)	0.0321 (0.0235)	0.1414 (0.0488)***
Log of exports	0.1554 (0.0557)***	0.0927 (0.0249)***	0.0330 (0.0287)	0.1553 (0.0567)***	0.0849 (0.0213)***	0.0260 (0.0298)	0.1667 (0.0558)***	0.0772 (0.0207)***	0.0390 (0.0303)
Log of the Duranton-Overman measure	–0.1222 (0.1085)	0.0059 (0.0818)	–0.1077 (0.0693)	–0.1235 (0.0965)	–0.0949 (0.0664)	–0.1983 (0.0886)**	–0.1137 (0.0956)	–0.0973 (0.0673)	–0.1955 (0.0904)**
High-tech				0.0035 (0.2508)	0.2783 (0.1459)*	0.2498 (0.1484)*			
High-tech (level 1)							0.2781 (0.2838)	0.1599 (0.1406)	0.1673 (0.1537)
High-tech (level 2)							0.9532 (0.2823)***	0.2239 (0.1410)	0.5521 (0.1715)***
High-tech (level 3)							–0.2567 (0.3297)	0.4499 (0.1802)**	0.0361 (0.1665)
High-tech (level 4)							–0.7587 (0.5756)	–0.0102 (0.2896)	0.4673 (0.2196)**
Observations	257	257	257	257	257	257	257	257	257
R-squared	0.96	0.97	0.89	0.96	0.97	0.89	0.97	0.97	0.90
	Measures Based on Firm Employment, Concentration Up to Distance of 15 km								
	1	2	3	1	2	3	1	2	3
Log of imports	0.0871 (0.0560)	0.0186 (0.0276)	0.1422 (0.0483)***	0.0878 (0.0561)	0.0209 (0.0252)	0.1478 (0.0427)***	0.0858 (0.0577)	0.0305 (0.0255)	0.1435 (0.0443)***
Log of exports	0.1594 (0.0576)***	0.0930 (0.0240)***	0.0352 (0.0292)	0.1585 (0.0578)***	0.0897 (0.0227)***	0.0269 (0.0299)	0.1543 (0.0541)***	0.0812 (0.0198)***	0.0291 (0.0298)
Log of the Duranton-Overman measure	0.0576 (0.0737)	0.0412 (0.0343)	-0.0760 (0.0546)	0.0416 (0.0972)	-0.0161 (0.0489)	-0.2222 (0.0856)**	0.0363 (0.0986)	-0.0168 (0.0500)	-0.2235 (0.0866)**
High-tech				0.0324 (0.1401)	0.1167 (0.0613)*	0.2975 (0.0916)*			
High-tech (level 1)							-0.0521 (0.1099)	0.0850 (0.0544)	0.3069 (0.0897)***
High-tech (level 2)							0.3147 (0.1209)***	0.0876 (0.0640)	0.3779 (0.0980)***
High-tech (level 3)							-0.2377 (0.3466)	0.4747 (.2260)**	0.0410 (0.1978)
High-tech (level 4)							-0.7879 (0.5935)	-0.0725 (0.1974)	0.1239 (0.2343)
Observations	257	257	257	257	257	257	257	257	257
R-squared	0.94	0.95	0.83	0.94	0.96	0.84	0.95	0.96	0.84

Notes: The dependent variables are: the log of manufacturing value-added (1); the log of average sectoral production wages (2); and the log of average sectoral non-production wages (3). All regressions include industry controls (industry size; Herfindahl index of sectoral employment concentration; number of establishments), a set of year dummies, and a set of industry dummies. Heteroskedasticity robust standard errors are in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table A-4: Results for the Lagged Difference Regressions

	Measures Based on Firm Counts, Concentration Up to Distance of 15 km								
	1	2	3	1	2	3	1	2	3
Δ log of imports	0.0149 (0.0830)	0.0615 (0.0316)*	0.1242 (0.0425)***	0.0131 (0.0879)	0.0681 (0.0327)**	0.1222 (0.0425)***	–0.0526 (0.0912)	0.0622 (0.0359)*	0.1236 (0.0447)***
Δ log of exports	–0.2401 (0.1077)**	–0.0056 (0.0336)	0.0109 (0.0395)	–0.2355 (0.1072)**	–0.0089 (0.0343)	0.0150 (0.0394)	–0.2103 (0.1032)**	–0.0160 (0.0367)	0.0155 (0.0417)
Δ log of the DO measure	0.0874 (0.1363)	–0.1323 (0.0795)	–0.1382 (0.0686)**	0.1659 (0.1649)	–0.1223 (0.0927)	–0.0742 (0.0843)	0.1918 (0.1748)	–0.1224 (0.0991)	–0.0795 (0.0878)
— for high-tech				–0.2864 (0.3328)	–0.0251 (0.1542)	–0.2345 (0.1105)**			
— for high-tech (level 1)							–0.3486 (0.4178)	–0.2525 (0.1070)**	–0.2693 (0.1632)
— for high-tech (level 2)							0.5061 (0.4577)	0.3189 (0.2054)	–0.0569 (0.2847)
— for high-tech (level 3)							–1.6324 (0.7994)**	0.0471 (0.2607)	–0.2558 (0.1729)
— for high-tech (level 4)							–0.0546 (0.3470)	–0.2273 (0.1653)	–0.3227 (0.3289)
Observations	85	85	85	85	85	85	85	85	85
R-squared	0.15	0.11	0.18	0.16	0.13	0.21	0.29	0.22	0.22
	Measures Based on Firm Employment, Concentration Up to Distance of 15 km								
	1	2	3	1	2	3	1	2	3
Δ log of imports	0.0058 (0.0845)	0.0466 (0.0301)	0.0956 (0.0423)**	0.0181 (0.0823)	0.0610 (0.0326)*	0.0916 (0.0440)**	-0.0733 (0.0964)	0.0540 (0.0400)	0.1171 (0.0463)**
Δ log of exports	-0.2475 (0.1050)**	-0.0025 (0.0351)	0.0104 (0.0404)	-0.2623 (0.1059)**	-0.0171 (0.0375)	0.0146 (0.0428)	-0.2278 (0.1088)**	-0.0213 (0.0417)	-0.0030 (0.0460)
Δ log of the DO measure	0.1204 (0.0800)	-0.0260 (0.0385)	0.0440 (0.0353)	0.0326 (0.1065)	-0.0796 (0.0583)	0.0619 (0.0568)	0.0649 (0.1107)	-0.0831 (0.0627)	0.0536 (0.0601)
— for high-tech				0.1683 (0.1330)	0.1188 (0.0606)*	-0.0377 (0.0734)			
— for high-tech (level 1)							0.1015 (0.1519)	0.0909 (0.0679)	0.0295 (0.0725)
— for high-tech (level 2)							0.2785 (0.1967)	0.1899 (0.0909)**	-0.0345 (0.1258)
— for high-tech (level 3)							-1.9038 (1.0689)*	0.2453 (0.4289)	-0.0660 (0.3930)
— for high-tech (level 4)							0.6066 (0.3144)*	0.1869 (0.1743)	-0.3289 (0.2889)
Observations	85	85	85	85	85	85	85	85	85
R-squared	0.16	0.06	0.14	0.17	0.10	0.14	0.27	0.16	0.18

Notes: All variables are (log) changes: between 2001 and 2005 for the independent variables, and between 2006 and 2009 for the dependent variables. The dependent variables are: the log of manufacturing value-added (1); the log of average sectoral production wages (2); and the log of average sectoral non-production wages (3). All regressions include industry controls (industry size; Herfindahl index of sectoral employment concentration; number of establishments), a set of year dummies, as well as high-tech and level *i* dummies. Heteroskedasticity robust standard errors in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.

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NOTES:

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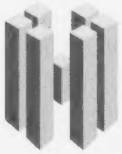

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